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(PROFESSIONAL PAPER.)

TESTS OF ROCKY MOUNTAIN WOODS FOR TELEPHONE POLES.

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POLE SUPPLY IN THE ROCKY MOUNTAIN REGION.

The rapid extension of telephone and power lines in the West makes the question of pole supply one of increasing importance. Tests described in this bulletin show that both green and fire-killed lodgepole pine and fire-killed Engelmann spruce will, under certain conditions, make suitable pole timbers. Western red cedar has long been the standard pole timber in the Western States. It has held its place mainly on account of its durability in contact with the soil, though its light weight has also been a very desirable feature. The tree (*Thuja plicata*) grows principally in Washington, Oregon, and northern Idaho. In addition to its wide use for poles, it is extensively cut for lumber, and especially for shingles. In the States south of its region of growth the cost of cedar is high, owing to the great distances over which it must be transported. Moreover, the heavy drain on the available supply must soon result in higher stumpage prices. There are at present in both the Rocky Mountain and Coast Ranges abundant stands of lodgepole pine (*Pinus contorta*), often called by local lumbermen "white pine," of little value for lumber, but well adapted for poles. Lodgepole pine is not naturally durable in contact with the ground, and for that reason has not been able to enter the field as a competitor of western red cedar. The general adoption of preservative treatment [1] by railroad and telephone companies, however, has changed the situation. At an additional cost for treatment that still leaves the pine pole the cheaper of the two in most of the markets outside the region where cedar grows, the pine may be made to last longer than untreated cedar. Lodgepole

[1] The preservative treatment of poles is discussed in Forest Service Bulletin 84.

Note.—This bulletin gives the results of tests on western red cedar, lodgepole pine, and Engelmann spruce poles to determine their suitability for telephone lines. Values are presented for fiber stress at elastic limit, modulus of rupture, stiffness, and modulus of elastic resilience. Of value to lumbermen in the Rocky Mountain and Pacific Coast States and to users of telephone poles.

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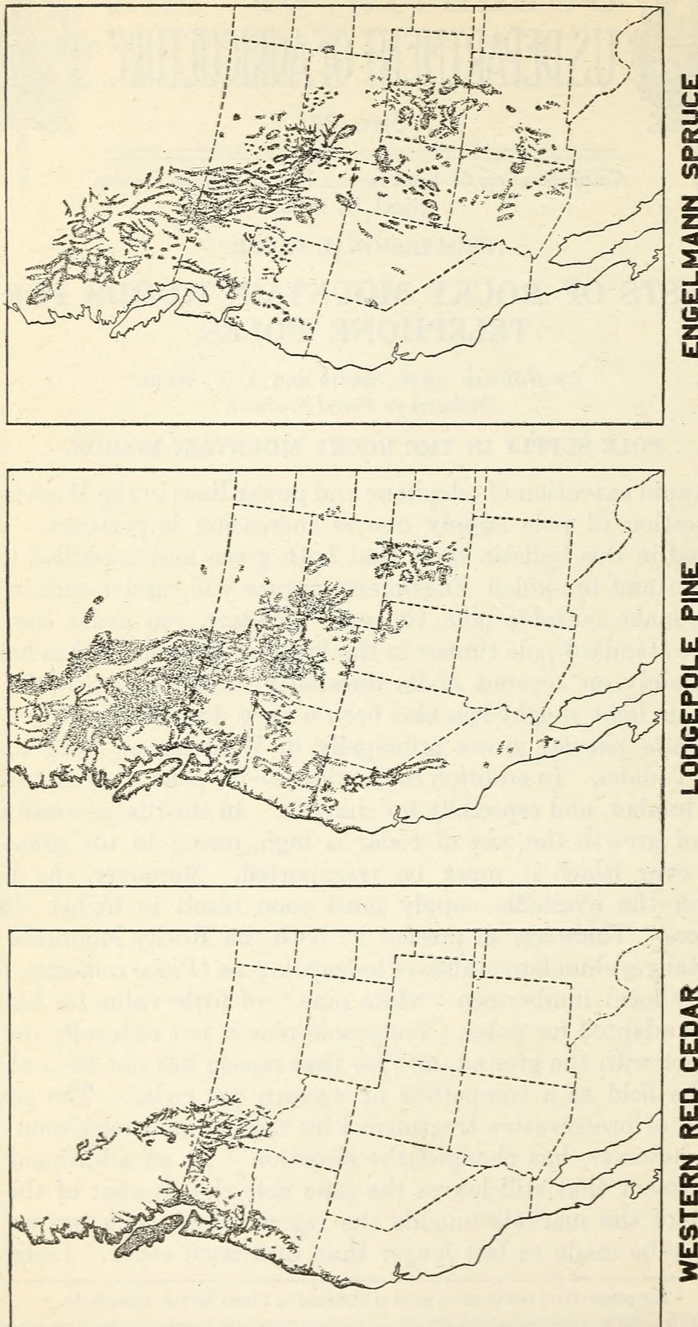

FIG. 1.—Botanical range of western red cedar, lodgepole pine, and Engelmann spruce.

pine takes treatment readily. Cedar, on the other hand, allows but a very shallow penetration.

Another tree, Engelmann spruce (*Picea engelmanni*) also has a wide distribution throughout the Rocky Mountains, although it grows commercially only at the higher altitudes. It is thus not as available as the lodgepole pine, nor in shape or in its ability to take preservative treatment is it so well adapted for poles. It grows farther south, however, and in many districts is the only native timber available for pole use. Figure 1[1] shows the botanical range of growth of the three species. The relatively restricted range of western red cedar indicates the importance to the more southern mountain States of determining the value of local timbers for telephone and power line poles.

Forest fires in the Rocky Mountains have killed many stands of spruce and pine, and the disposal of this material, which, through checking, is rendered practically useless for saw timber, has always been a troublesome problem. On many areas such material remains entirely sound for a number of years after the fire, and, besides, is thoroughly seasoned and thus ready for treatment as soon as cut. In some regions the mines use all the available dead timber, though elsewhere there is a great deal of prejudice against the use of "fire-killed" material, under the mistaken assumption that there is some inherent difference in wood that has been seasoned on the stump and wood that has been cut when green.

The purpose of the tests described in this bulletin was: (1) To compare the strength of poles of western red cedar, the present standard, and of lodgepole pine and Engelmann spruce, and (2) to determine the value for pole timber of fire-killed pine and spruce in the central Rocky Mountain region.

The fire-killed material was donated by the Colorado Telephone Co. and the Central Colorado Power Co. The remainder of the material tested was secured by the Forest Service, either by purchase or from the National Forests. The tests were made at the Forest Service timber-testing laboratory conducted in cooperation with the University of Colorado, Boulder, Colo.

MATERIAL TESTED.

The material for the tests consisted of poles nominally 25 feet long and of 7 inches top diameter. Average material was specified in each case.

WESTERN RED CEDAR.

Twenty cedar poles were purchased on the Denver market at a cost of $4 per pole. Information furnished by the seller showed the poles to have been cut during the winter of 1908–9, near Edgemere, Idaho. When received at the laboratory they appeared to be

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[1] Distribution maps prepared by Office of Dendrology.

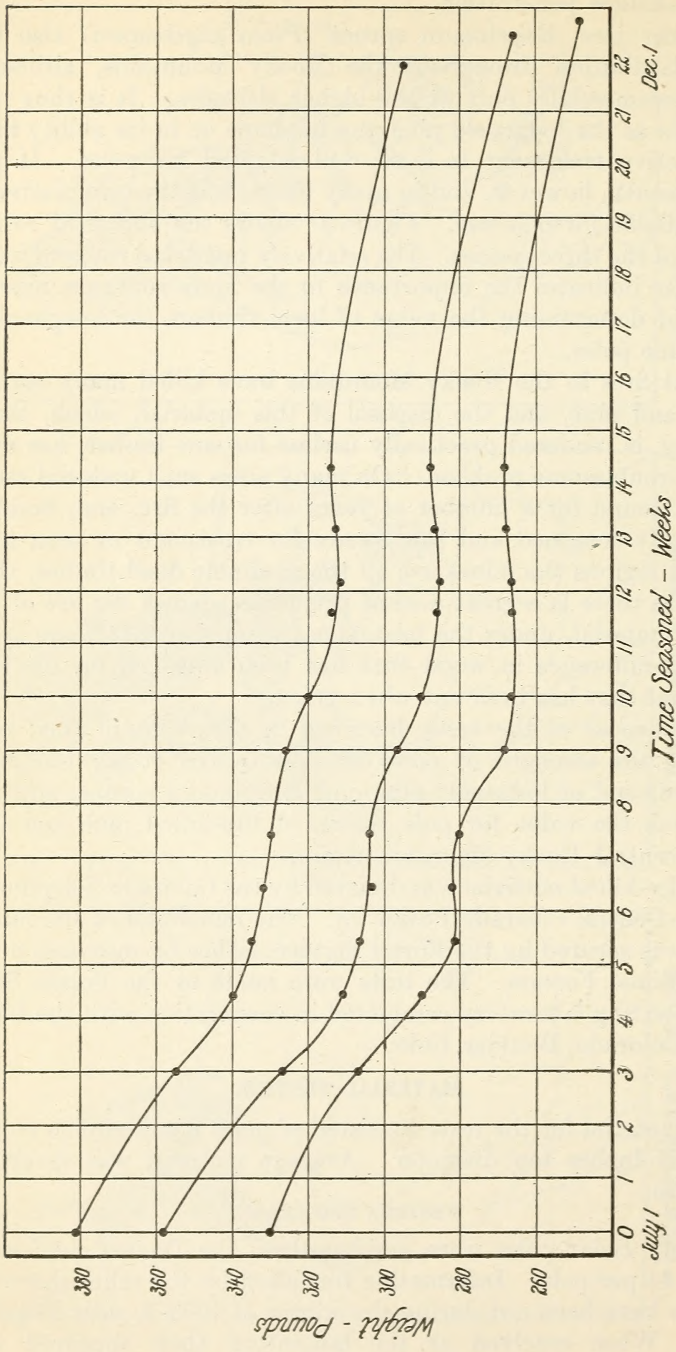

FIG. 2.—Rate of seasoning for three lodgepole pine poles.

thoroughly seasoned, the bark probably having been removed at the time of cutting. All were nearly straight, and checked to the extent usual for seasoned material. A majority had straight grain.

GREEN LODGEPOLE PINE.

Twenty-two lodgepole pine poles were cut near Anaconda, Mont., in July, 1911, on the Deerlodge National Forest, in a dense stand

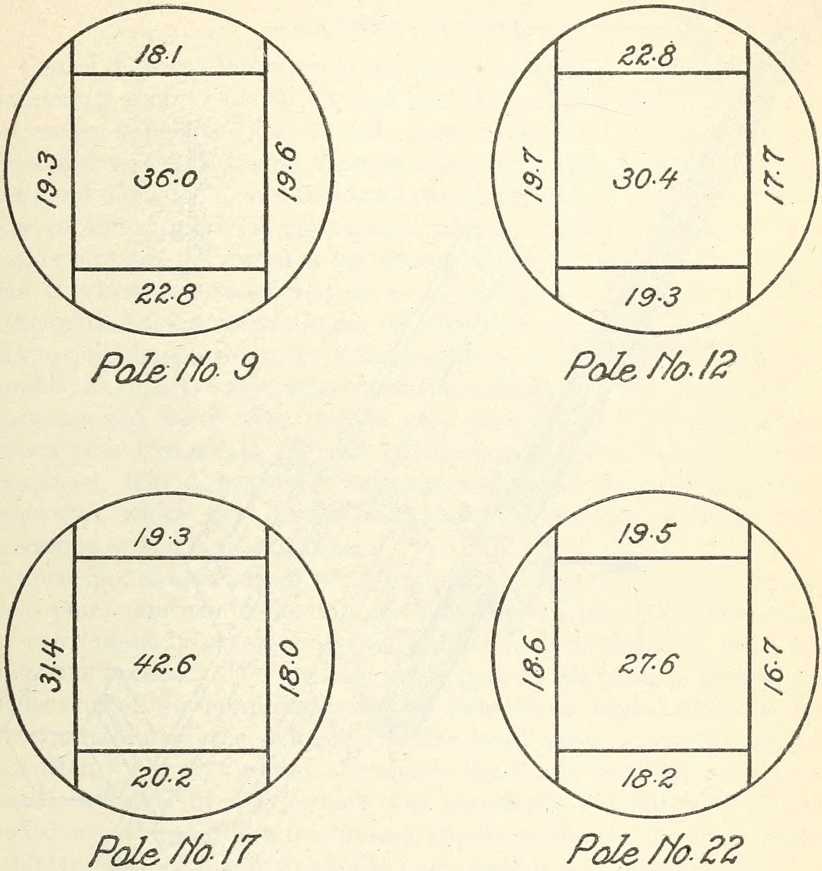

FIG. 3.—Moisture distribution in four air-seasoned lodgepole pine poles. Figures indicate per cent moisture within areas.

on a gentle west slope at an elevation of about 6,500 feet. Upon arrival at the testing laboratory the poles were open-piled in two layers for seasoning. Three poles were weighed at approximately weekly intervals to determine the rate of drying. Figure 2 shows graphically the rate based on these weights. Based on their shipping weight the poles had an average moisture content of 60 per cent when shipped. Assuming that the three poles represent the average of the shipment, the poles had dropped to 48 per cent moisture by the time they reached the laboratory. After 12 weeks' seasoning they had reached 30 per cent, and for 3 weeks thereafter their moisture content remained practically stationary, due probably to a period of damp weather. The weights taken at the time of test show that after seasoning for 22 weeks, practically from the 1st of July to the

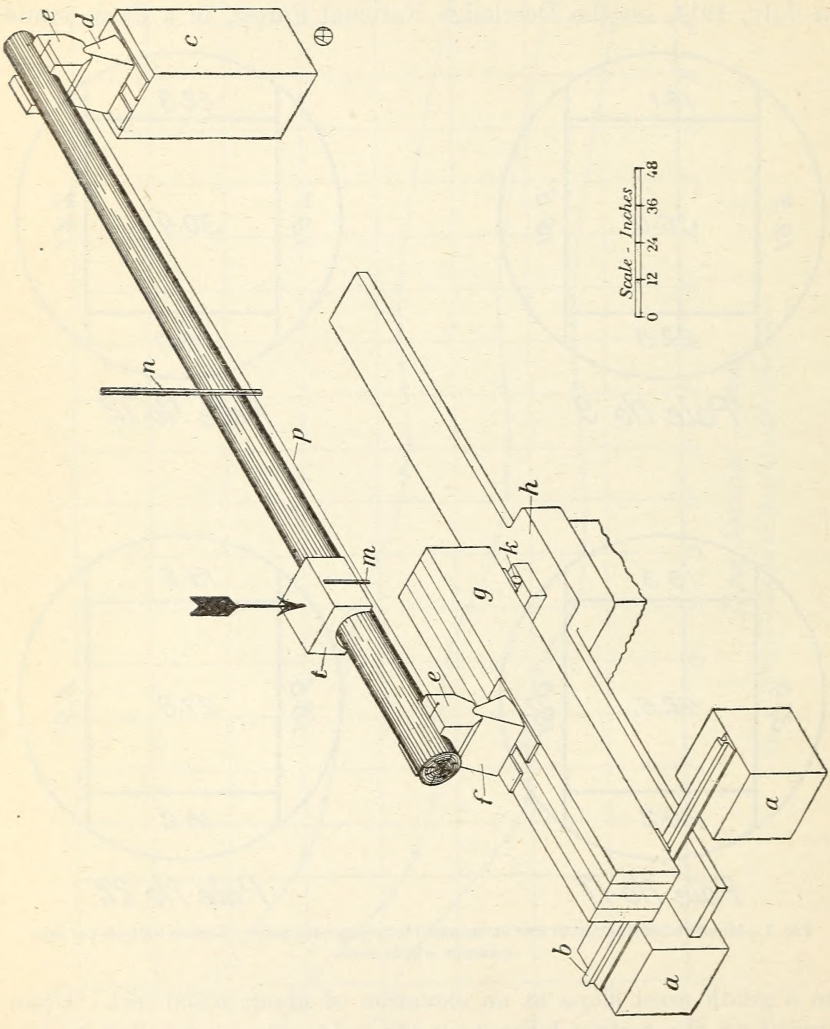

FIG. 4.—Method of testing poles.

1st of December, the poles contained about 22 per cent moisture. Figure 3 shows the moisture distribution in four of the poles at the time of test. It indicates that the center of the poles was still at or above the fiber saturation point[1] when tested. The poles checked considerably during the seasoning, but not to an unusual extent.

[1] For a detailed discussion of the fiber saturation point see Forest Service Circular 108, The Strength of Wood as Influenced by Moisture, by H. D. Tiemann.

FIRE-KILLED LODGEPOLE PINE AND ENGELMANN SPRUCE.

Twenty poles each of fire-killed lodgepole pine and Engelmann spruce were cut near Norrie, Colo., on a north slope at an elevation of about 10,000 feet. The area had been burned over by a light fire about 10 years[1] previously. The poles were largely free of bark, though a majority had patches here and there, showing that no serious weathering of the surface had taken place.

METHODS OF TEST.

Figure 4 shows the method employed in testing. The poles were supported about 1 foot from each end in bearing blocks (*e*, *e*) resting on rocker supports (*f*, *d*) 23 feet apart. The load was applied by a universal testing machine through a bearing block (*t*) 5 feet from the butt end of the pole, or 4 feet from the center line of the butt support. The rocker support (*d*) rested on a pier (*c*) built on the floor. The rocker support (*f*) rested at the center of the auxiliary beam (*g*), one end of which was supported by a rail (*b*) and two piers (*a*, *a*). The other end of the auxiliary beam (*g*) rested on a roller (*k*) in the center of the weighing platform (*h*) of the machine. As the load was gradually applied at *t* the pole deflected, and the scale at *n*, at the center of the span, moved down with respect to a taut spring (*p*) stretched between pins driven into the pole on the neutral axis directly over the supports. The deflection of the pole at the load point was read on a scale (*m*), which gave the movement of the machine head (*t*) with reference to the platform (*h*).

Corresponding readings of the applied load, the deflection at the load point, and the deflection at the middle of the span were taken at convenient intervals, and plotted as shown in figure 5, until the pole was broken. The settling of the pole in the bearing blocks and deflection of the auxiliary beam (*g*) introduced slight errors in the determination of the deflection. The total error was estimated as less than 3 per cent within the elastic limit, and the only calculated results affected by this (which was practically constant for all the poles) are the stiffness factor and elastic resilience, both of which are comparable only with results from tests of the same nature.

From each pole after test a 30-inch section of clear wood was taken and cut into 2 by 2 inch sticks. These were tested in bending, in compression parallel to the grain, compression perpendicular to the grain, and shearing. The method employed in making these minor tests is discussed fully in Forest Service Circular 38 (revised). The purpose of these tests was to determine the influence of defects on the strength of the poles.

The poles in each of the four lots were given consecutive numbers starting with 1, in order to distinguish between the individual poles of each lot.

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[1] The date of the fire was obtained from local residents.

To determine the moisture content, a 1-inch section was cut from each pole as near as possible to the point of failure, immediately weighed, and later dried to constant weight at the temperature of

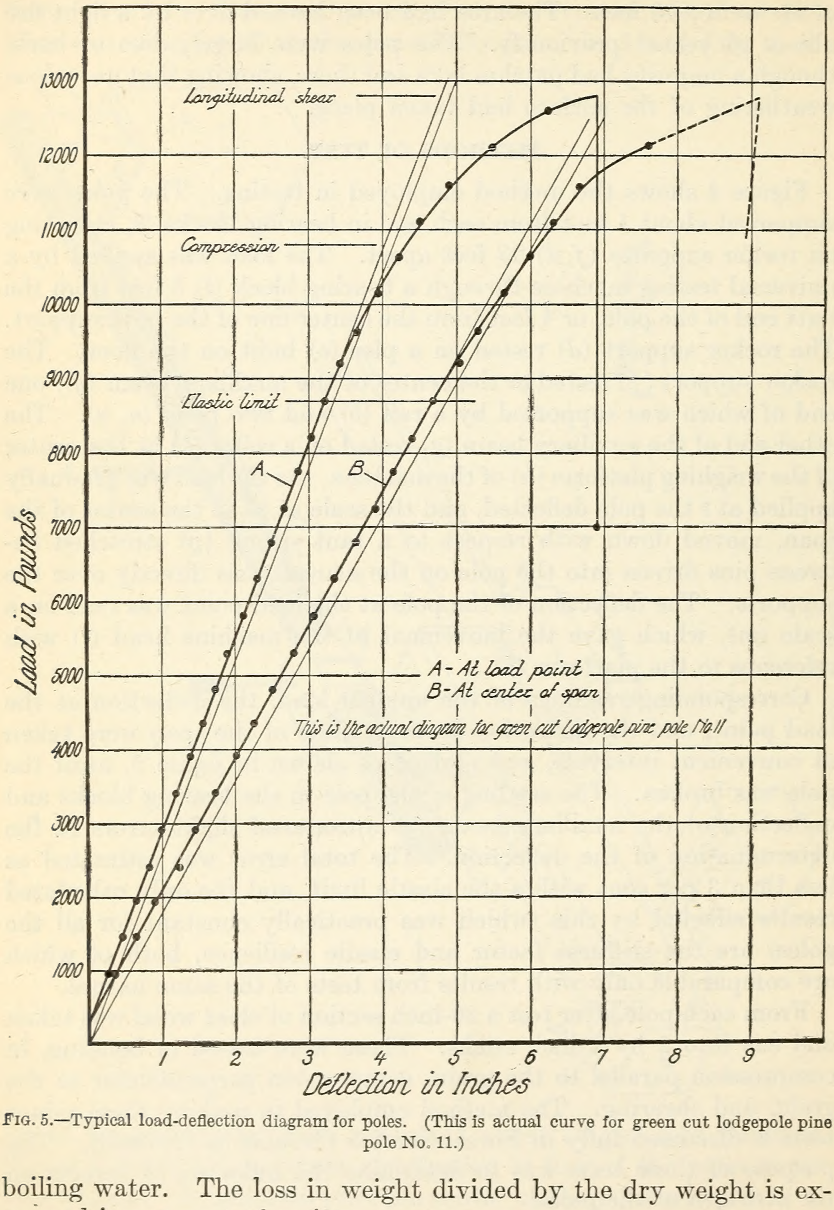

FIG. 5.—Typical load-deflection diagram for poles. (This is actual curve for green cut lodgepole pine pole No. 11.)

boiling water. The loss in weight divided by the dry weight is expressed in per cent of moisture.

The length, weight, and diameters of the poles were obtained just before testing. The age, rings per inch, per cent sap, and per cent summerwood were obtained after test from a section cut near the point of failure. The values for the amount of summerwood were obtained on a 2-inch length taken from an average portion of the section. Sketches were made of the manner of failure, principal defects, and any characteristics peculiar to the poles tested.

METHOD OF COMPUTING RESULTS.

The deflections and loads at elastic limit were taken from the load-deformation curves, a sample of which is shown in figure 5. To reduce the load recorded on the scale beam to the true load on the pole, all recorded values were multipled by $\frac{23}{19}\times 2$, and appear in the tables in the corrected form. Stresses at elastic limit and maximum load were calculated for the outer fiber under the load point. The moment of three-fourths of the weight of the pole was added to the moment produced by the load. The comparative stiffness is expressed by the relation $\frac{P}{Id}$, when P is the load at elastic limit and I and *d*, respectively, the moment of inertia and the deflection at elastic limit measured at the load point.

The modulus of elastic resilience was obtained from the formula one-half P*d* ÷ volume. In obtaining the volumes there was found to be considerable difference in the shape of the poles. The spruce and pine were practically of even taper, and the volumes obtained by regarding the whole pole as one frustum of a cone (from top to butt diameter), or as two frustums (from top to center and center to butt), were practically the same. In the cedar, however, it was found necessary, on account of the flared butts, to use a three-frustum method (from top to center, from center to load point, and from load point to butt). There was about 10 per cent difference between results from the one and the three frustum methods with this species. In calculating the dry weight per cubic foot, a total shrinkage of 12 per cent for the fire-killed pine and spruce was assumed, and 10 per cent for the cedar. The air-seasoned pine poles were considered as being one-third below the fiber saturation point (that is, a 4 per cent shrinkage in volume was assumed as having already occurred), and the others were assumed as being half-way between the dry and the fiber-saturated states.

RESULTS OF TESTS.

CHARACTER OF FAILURES.

Figure 6 shows the common types of failures occurring in the poles tested.

The bend of the pole while under load was at a maximum near the center of the span for the first part of the test and about 2 feet nearer the load point at maximum load. This shifting at the point of greatest deflection was most noticeable in the poles having a tendency toward longitudinal shear. The effect of knots was in evidence only as localizing the compression wrinkles and occasionally

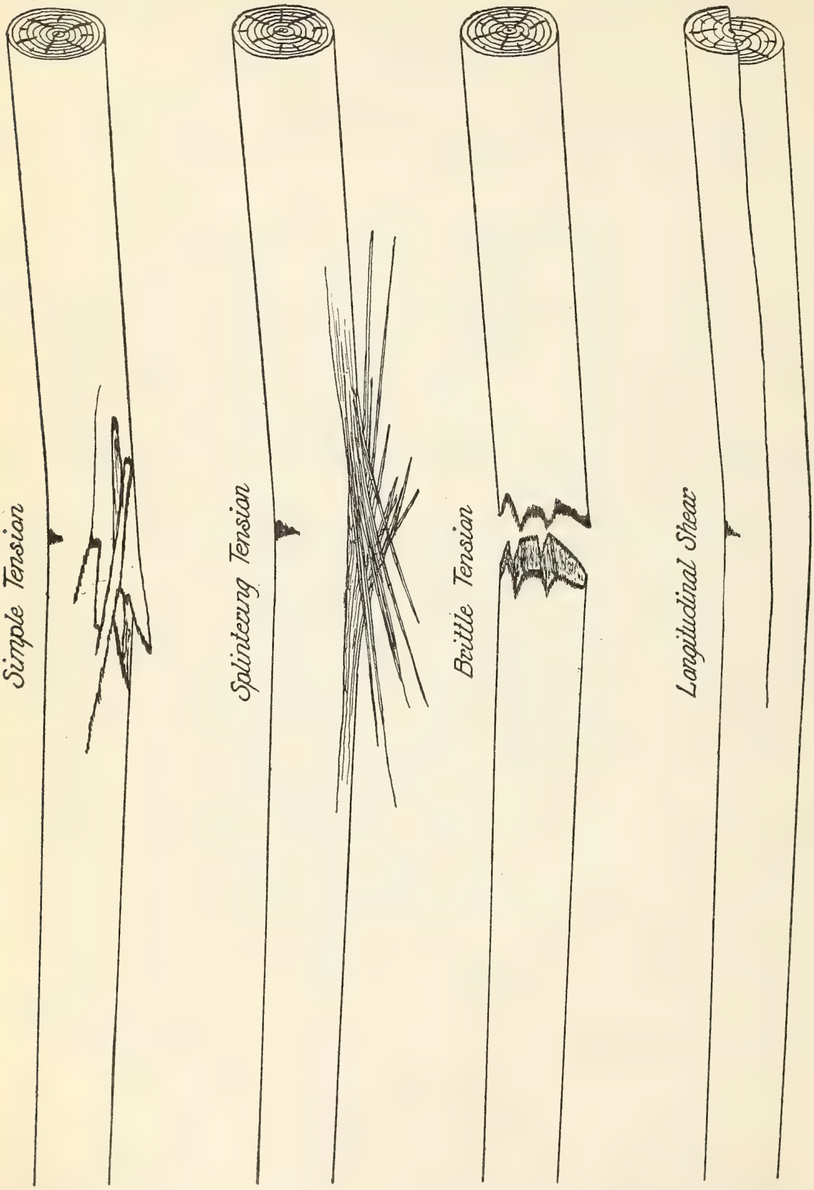

FIG. 6.—Types of failures in poles.

at the starting point of a tension crack. In the cedar poles many shallow ax cuts had been made when the bark was removed, and tension failures always took advantage of these breaks in the fibers.

There seemed to be no consistent difference in the behavior of straight and spiral grain poles.

The typical failure of the western red cedar poles was a splintering tension about 2 feet from the load point. The wood separated easily along the annual rings, and the splinters were long and numerous. Probably due to this quality, as well as to the depth of checks, three poles failed in longitudinal shear, and in two others shear occurred after the maximum load had been passed.

In the air-seasoned lodgepole pine poles there were 18 tension failures and 4 failures from longitudinal shear. Of the 18 tension failures, 9 were of the splintering type characteristic of the cedar poles and 9 were simple tension failures; that is, without the exhibition of brittleness or unusual splintering.

The typical failure in fire-killed lodgepole pine was a simple tension close to the load point. The wood often had a rather brash appearance, and, except for two poles, did not splinter to any extent. One pole was brittle, failing near the center, and one failed by longitudinal shear after the maximum load had been passed.

In general the fire-killed Engelmann spruce poles failed in the same manner as the fire-killed lodgepole pine. Two poles had brittle tension failures, and there were no longitudinal shear failures.

The fact that 9 of the 42 air-seasoned and only 1 of the 40 fire-killed poles failed by longitudinal shear might seem at first to indicate that the checking of the poles cut from green timber is deeper than that occurring in the more slowly drying fire-killed poles. The fact, however, that the average shearing stress of the cedar proved to be about 15 per cent lower than that of the other species, and further that the moduli of rupture in bending of both green-cut shipments were higher than those obtained in both fire-killed shipments, shows that there was a greater chance for shear failures in the air-seasoned material than in the fire-killed, aside from any difference in the manner of checking.

Compression of the upper fibers, as shown by wrinkles on the top of the pole, occurred some time before the maximum load was reached. There was usually a noticeable increase in the bend of the load-deflection curve after compression became visible.

TABLE 1.—*Results of individual tests.*

WESTERN RED CEDAR POLES CUT GREEN AND AIR SEASONED.

Pole and reference No.	Grain.	Per cent moisture.	Weight of pole at test.	Length.	Diameter at—				Approximate age.	Rings per inch.	Per cent summerwood.	Per cent sap.	Weight per cubic foot (oven dry).	Fiber stress at elastic limit.	Modulus of rupture.	Stiffness factor.	Modulus of elastic resilience.	Manner of failure.
					Top.	Center.	Load point.	Butt.										
			Lbs.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Yrs.*				*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*In. lbs. per cu. in.*	
1	Straight	15.5	222	302¾	7.06	8.28	8.99	10.03	84	20	.....	24	20.9	4,945	6,550	6.07	1.19	Tension at load; split along shake.
2	.....do	16.4	211	304¼	6.58	7.58	8.58	10.17	101	22	23	37	22.0	4,120	6,370	6.04	.92	Simple tension 40 inches from load.
3	.....do	16.7	240	305	7.03	9.00	9.87	11.10	104	20	22	33	19.3	3,530	5,400	4.43	.94	Simple tension 78 inches from load, separation on annual rings.
4	.....do	15.8	228	304	7.16	8.22	9.53	10.51	97	19	18	43	20.5	2,900	5,560	4.62	.62	Splintering tension 66 inches from load.
5	.....do	30.8	233	303¾	6.78	7.75	9.10	10.58	91	18	21	38	20.2	3,990	5,480	4.99	1.09	Splintering tension 36 inches from load.
6	.....do	14.5	224	304¾	7.20	7.96	8.85	10.19	94	21	25	27	21.8	3,770	6,930	6.58	.68	Splintering tension at load.
7	.....do	17.3	247	304	7.32	8.75	9.91	11.61	68	13	13	29	19.6	3,780	5,090	4.46	1.08	Splintering tension 12 inches from load.
8	Spiral	18.5	208	303¼	6.98	7.90	8.47	10.67	83	19	14	37	20.2	4,130	6,870	7.43	.68	Simple tension at load.
9	Straight	13.0	192	308¼	6.15	7.48	8.00	8.77	55	14	17	38	23.1	5,350	8,120	8.90	1.00	Do.
10	Spiral	14.2	251	299¼	6.84	8.28	9.37	11.50	83	17	22	36	22.9	4,500	6,650	6.30	1.06	Splintering tension at load.
11	Straight	13.5	210	301	6.96	7.98	8.57	8.75	83	19	20	26	22.2	4,610	5,550	8.50	.80	Longitudinal shear along checks.
12	.....do	14.1	259	304½	7.18	8.58	9.65	11.44	101	20	18	21	22.5	4,230	7,720	6.25	.96	Tension and compression followed by shear.
13	.....do	13.8	245	305½	7.19	8.36	9.37	11.40	101	20	21	32	21.8	4,260	6,770	5.64	1.03	Splintering tension 48 inches from load.
14	.....do	12.1	179	301¾	6.37	7.33	7.97	8.52	81	20	17	27	22.4	4,940	8,220	8.49	.92	Splintering tension 24 inches from load.
15	.....do	12.0	202	304½	7.00	7.88	8.76	10.11	69	17	17	32	20.7	3,880	7,600	6.40	.75	Tension and compression followed by shear.
16	.....do	12.6	195	303	6.89	7.79	8.11	8.22	79	20	18	25	22.2	5,980	8,190	9.05	1.21	Longitudinal shear.
17	.....do	14.5	239	297½	7.46	8.38	9.11	9.65	79	17	20	38	22.4	5,030	6,830	6.70	1.22	Splintering tension 24 inches from load.
18	Spiral	12.2	200	306	6.83	7.84	8.47	10.10	69	16	17	33	21.0	4,450	7,800	7.62	.80	Splintering tension 36 inches from load.
19	.....do	12.1	219	304	7.42	8.06	8.83	11.80	71	15	11	29	20.4	4,500	6,640	7.10	.85	Do.
20	Straight	12.0	238	303½	7.25	8.22	8.50	10.12	95	21	17	24	22.1	5,700	9,360	9.46	1.01	Longitudinal shear.
	Average	15.1	222	......	6.98	8.07	8.90	10.26	84	18.4	18	32	21.4	4,430	6,885	6.75	.94	
	Maximum	30.8	259	......	7.46	9.00	9.91	11.80	104	22.0	25	43	23.1	5,980	9,360	9.46	1.22	
	Minimum	12.0	179	......	6.15	7.33	7.97	8.22	55	13.0	11	21	19.3	2,900	5,090	4.43	.62	
	LODGEPOLE PINE POLES CUT GREEN AND AIR SEASONED.																	
1	Spiral	21.9	363	308	8.30	9.38	10.00	11.00	165	30	.....	48	25.5	3,830	5,190	6.35	0.69	Simple tension 12 inches from load.
2	Straight	20.9	252	306¼	6.90	7.75	8.50	9.50	161	34	.....	39	25.5	4,580	6,830	7.30	.88	Splintering tension 18 inches from load.
3	Spiral	21.0	257	307½	6.70	7.50	8.30	8.70	155	35	.....	53	28.6	5,600	7,700	7.13	1.43	Simple tension 12 inches from load.

4	Straight	21.8	314	305½	7.60	8.60	9.20	10.00	165	33	.....	63	26.6	5,650	8,290	8.47	1.16	Splintering tension 12 inches from load.
5	Spiral	21.4	266	306½	7.00	7.68	8.25	8.75	149	34	.....	40	28.4	4,840	8,050	8.81	.81	Simple tension 12 inches from load.
6	Straight	19.7	280	308½	7.10	7.80	8.15	8.65	162	38	.....	56	29.6	5,390	9,500	10.60	.80	Splintering tension 18 inches from load.
7	do	24.5	284	318½	6.75	7.65	8.75	9.00	163	36	.....	42	28.5	5,380	7,000	7.01	1.43	Splintering tension 12 inches from load.
8	do	24.0	375	307½	8.00	8.90	9.50	10.00	165	33	.....	58	29.0	5,260	7,790	9.07	.93	Longitudinal shear.
9	Spiral	21.4	317	309	7.70	8.65	9.00	10.25	159	31	.....	35	26.0	5,760	7,190	8.41	1.13	Splintering tension 12 inches from load; brash.
10	do	24.5	296	307	7.25	8.00	8.40	8.75	162	37	.....	39	29.1	5,760	7,750	9.62	1.03	Simple tension 8 inches from load.
11	Straight	23.8	285	308½	7.50	8.25	9.00	9.50	159	33	.....	46	25.5	4,940	7,210	8.00	.96	Longitudinal shear.
12	Spiral	22.2	351	318¼	8.00	9.00	9.25	9.70	170	35	.....	34	27.2	4,830	7,380	8.66	.79	Simple tension at load.
13	do	21.8	351	309¼	7.80	8.80	9.25	9.50	156	33	.....	47	29.6	5,920	7,870	8.90	1.22	Do.
14	Straight	18.5	253	307¾	6.80	7.70	8.50	9.25	160	35	.....	56	26.7	5,220	7,420	7.85	1.10	Splintering tension 18 inches from load.
15	Spiral	19.4	268	307¼	6.75	7.70	8.15	9.20	166	36	.....	57	28.4	5,920	9,230	10.80	.95	Longitudinal shear.
16	do	21.4	384	305¾	8.30	9.30	9.80	11.00	165	30	.....	38	27.4	5,310	7,640	9.39	.88	Do.
17	do	21.4	272	305½	6.85	7.75	8.20	8.50	161	38	.....	49	29.4	5,280	7,950	9.58	.89	Simple tension 24 inches from load.
18	do	19.4	313	305½	7.50	8.45	9.00	10.00	165	33	.....	59	27.7	5,770	8,530	9.52	1.05	Do.
19	do	34.8	373	309¾	7.85	9.25	9.60	9.85	144	29	.....	37	26.1	4,330	6,410	7.35	.78	Splintering tension 24 inches from load.
20	Straight	20.4	335	307½	7.70	8.75	9.60	10.25	167	33	.....	51	27.5	4,530	6,540	7.92	.83	Simple tension at load.
21	do	18.5	270	307	6.75	7.70	8.30	9.30	168	36	.....	75	28.7	5,950	8,860	9.78	1.10	Splintering tension at load.
22	do	20.4	248	306½	6.75	7.70	8.15	8.75	170	39	.....	43	26.9	6,270	8,670	9.47	1.27	Do.
	Average	21.9	304	.....	7.36	8.28	8.85	9.52	162	34	.....	48	27.6	5,280	7,680	8.62	1.00	
	Maximum	34.8	384	.....	8.30	9.38	10.00	11.00	170	39	.....	75	29.6	6,270	9,500	10.80	1.43	
	Minimum	18.5	248	.....	6.70	7.65	8.15	8.50	144	29	.....	34	25.5	3,830	5,190	6.35	.69	

LODGEPOLE PINE POLES FIRE KILLED 10 YEARS.

1	Straight	11.2	250	310	7.30	8.60	.....	9.60	140	27	11	21	23.1	2,230	2,230	4.42	0.34	Brittle tension 108 inches from load.
2	do	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Not tested; broken in shipment.
3	do	14.6	267	309½	7.25	8.50	.....	9.50	142	32	14½	32	24.6	3,355	3,495	5.70	.62	Simple tension 96 inches from load; brash.
4	do	11.9	310	311½	7.50	8.50	.....	9.25	184	38	16	20	29.1	6,130	6,540	8.46	1.38	Simple tension at load.
5	do	22.4	286	309¾	7.25	8.62	.....	9.00	143	29	17	36	25.0	5,060	7,480	8.72	.84	Do.
6	do	12.8	270	309	6.75	8.12	.....	8.75	130	29	13	21	28.4	5,860	7,140	6.68	1.62	Simple tension 84 inches from load.
7	do	12.9	303	311½	7.75	8.50	.....	9.50	170	34	18	37	27.4	5,560	7,420	6.63	1.45	Simple tension at load.
8	do	16.8	273	311½	7.50	9.00	.....	9.00	189	39	19	48	23.5	4,940	5,720	7.08	1.03	Do.
9	do	20.8	411	312	9.25	10.25	.....	10.75	97	17	14	27	24.7	2,605	3,775	5.18	.38	Simple tension at load; brash.
10	Spiral	19.7	294	312	7.25	8.88	.....	9.50	148	31	15	60	24.5	3,575	5,610	6.11	.64	Simple tension 12 inches from load.
11	Straight	18.2	305	309½	7.50	8.88	.....	9.00	152	31	15	40	26.5	5,030	7,030	7.04	1.07	Simple tension at load; brash.
12	Spiral	14.8	315	311	7.50	9.25	.....	10.50	170	28	19	30	24.5	4,780	6,710	4.91	1.54	Simple tension 48 inches from load.
13	do	13.9	290	310½	7.25	8.62	.....	14.75	140	33	9	37	.....	4,130	5,290	6.02	.99	Splintering tension 42 inches from load.
14	do	12.0	360	311	8.25	9.00	.....	10.00	150	32	7	24	29.3	5,650	6,760	7.26	1.36	Simple tension 21 inches from load.
15	Straight	18.1	257	311¼	7.25	8.25	.....	9.50	180	39	10	38	23.5	3,325	4,130	4.57	.76	Simple tension 24 inches from load.
16	do	13.6	266	311	7.25	8.25	.....	9.50	140	33	11	19	25.2	5,480	7,190	6.68	1.45	Splintering tension at load.
17	do	36.2	412	309½	8.00	9.38	.....	9.75	143	33	13	31	27.2	2,790	3,740	5.56	.40	Simple tension at load.
18	Spiral	18.5	255	310½	7.00	8.25	.....	9.00	170	42	10	20	24.4	4,280	5,110	6.08	.94	Simple tension 12 inches from load.
19	do	14.3	258	311½	7.00	8.38	.....	9.25	170	40	13	40	24.7	3,980	4,600	5.54	.90	Simple tension 12 inches from load; brash.
20	do	18.6	335	310½	7.75	8.88	.....	13.50	178	38	12	21	21.6	3,460	4,160	6.17	.71	Simple tension at load.
	Average	16.9	301	.....	7.50	8.74	.....	9.93	155	31.8	13.5	32	25.4	4,327	5,481	6.25	.97	
	Maximum	36.2	412	.....	9.25	10.25	.....	14.75	189	42.0	19.0	60	29.3	6,130	7,480	8.72	1.62	
	Minimum	11.2	250	.....	6.75	8.13	.....	8.75	97	17.0	7.0	19	21.6	2,230	2,230	4.42	.34	

TABLE 1.—*Results of individual tests*—Continued.

ENGELMANN SPRUCE POLES FIRE KILLED 10 YEARS.

Pole and reference No.	Grain.	Per cent moisture.	Weight of pole at test.	Length.	Diameter at— Top.	Diameter at— Center.	Diameter at— Load point.	Diameter at— Butt.	Approximate age.	Rings per inch.	Per cent summerwood.	Per cent sap.	Weight per cubic foot (oven dry).	Fiber stress at elastic limit.	Modulus of rupture.	Stiffness factor.	Modulus of elastic resilience.	Manner of failure.
			Lbs.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Yrs.*				*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*In. lbs. per cu. in.*	
1	Straight	16.1	293	312½	7.75	9.50	......	11.00	198	41	16	....	20.8	3,730	3,820	4.36	1.06	Simple tension at load.
2	Spiral	12.9	262	309½	7.50	9.00	......	9.50	128	30	10	....	22.8	4,720	5,800	6.97	1.00	Do.
3	do	11.9	219	310½	7.00	8.25	......	10.25	142	28	14	....	20.4	3,260	4,020	4.33	.84	Do.
4	do	19.0	285	308¾	6.75	8.50	......	9.25	184	44	17	....	26.3	3,680	4,220	6.92	.61	Do.
5	Straight	13.9	177	310	6.00	7.25	......	9.75	115	31	19	....	20.1	2,710	3,890	3.90	.69	Do.
6	do	13.8	275	309¼	7.50	9.00	......	9.50	192	34	10	....	23.7	5,210	6,020	6.88	1.22	Do.
7	do	17.1	313	311	7.50	9.25	......	10.50	175	30	19	....	23.9	4,100	5,000	6.73	.82	Do.
8	do	14.0	296	311¼	7.00	8.75	......	11.00	195	43	11	....	24.3	4,450	6,070	5.58	1.25	Simple tension 8 inches from load; brash.
9	do	18.8	213	312¾	6.25	8.25	......	10.50	134	29	17	....	19.0	2,290	3,240	3.30	.56	Brittle tension 66 inches from load.
10	Spiral	14.3	251	311	7.25	8.50	......	9.75	198	43	18	....	22.6	4,540	5,850	6.70	1.00	Simple tension at load.
11	do	12.2	306	310½	7.25	9.00	......	11.62	150	30	15	....	23.8	2,790	3,850	4.13	.63	Do.
12	Straight	15.0	313	307½	7.25	9.50	......	11.25	140	31	9	....	22.9	4,100	4,580	4.66	1.23	Simple tension 36 inches from load.
13	Spiral	18.0	292	309½	7.25	9.12	......	10.50	195	42	15	....	22.7	3,550	4,340	5.85	.72	Simple tension 60 inches from load.
14	do	18.3	273	311¼	7.25	9.00	......	10.50	112	25	14	....	21.4	3,110	3,720	4.42	.72	Simple tension 8 inches from load.
15	Straight	14.7	332	313¼	8.00	9.75	......	11.50	180	40	17	....	22.4	3,620	4,930	4.66	.96	Splintering tension 15 inches from load.
16	Spiral	14.9	249	311¼	7.25	8.75	......	10.75	210	34	20	....	20.4	3,260	3,490	3.95	.91	Splintering tension 18 inches from load.
17	Straight	15.6	280	312	7.75	8.75	......	11.00	162	25	19	....	21.8	2,930	3,980	4.16	.69	Simple tension 6 inches from load.
18	Spiral	32.8	237	311	6.75	8.00	......	10.25	155	38	13	....	19.3	2,180	2,180	3.56	.44	Brittle tension at load.
19	do	13.8	317	310½	7.50	9.00	......	11.50	190	46	24	....	24.1	2,950	4,220	4.21	.72	Simple tension at load.
20	do	18.4	299	312¼	8.00	9.00	......	10.75	120	23	14	....	22.3	2,600	4,340	4.08	.53	Simple tension 24 inches from load.
	Average	16.3	274	......	7.23	8.80	......	10.53	164	34.3	16	....	22.3	3,489	4,378	4.97	0.83	
	Maximum	32.8	332	......	8.00	9.75	......	11.63	210	46.0	24	....	26.3	5,210	6,070	6.97	1.25	
	Minimum	11.9	177	......	6.00	7.25	......	9.25	112	23.0	9	....	19.0	2,180	2,180	3.30	0.44	

POLES.

Table 1 gives the test data for individual poles.

Table 2 gives the maximum load of each pole in terms of both the equivalent pull at the top and the actual load obtained in the testing machine at the ground line. This table is of value chiefly in comparing the results of these tests with those from other methods of applying the load, as all may be reduced to the reaction at the top support for poles of the same size.

Table 3 gives a summary and comparison of the average results obtained in the tests on the four classes of poles, based on the western red cedar as 100. On a basis of fiber stress developed it will be seen that—

1. Air-seasoned lodgepole pine is superior to western red cedar in all the mechanical properties determined.

2. Fire-killed lodgepole pine is only 80 per cent as strong as western red cedar at maximum load. In elastic values, however—that is, the fiber stress at elastic limit and the work absorbed up to this point—they are practically equal. In stiffness the fire-killed lodgepole pine is quite comparable to the cedar, although the latter proved to be a more flexible wood.

3. Fire-killed Engelmann spruce was inferior in all mechanical properties to the cedar and pine.

TABLE 2.—*Top and ground-line loads required to break poles.*

Pole No.	Western red cedar, cut green and air seasoned.		Lodgepole pine, cut green and air seasoned.		Lodgepole pine fire killed 10 years.		Engelmann spruce fire killed 10 years.	
	Top reaction at maximum load.	Maximum load at ground line.	Top reaction at maximum load.	Maximum load at ground line.	Top reaction at maximum load.	Maximum load at ground line.	Top reaction at maximum load.	Maximum load at ground line.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	2,020	11,600	2,185	12,580	714	4,110	1,811	10,410
2	1,705	9,800	1,770	10,190			1,980	11,390
3	2,238	12,870	1,866	10,720	1,094	6,290	1,431	8,230
4	2,075	11,920	2,740	15,730	1,980	11,380	1,262	7,260
5	1,745	10,030	1,913	11,000	2,000	11,500	1,094	6,290
6	2,070	11,900	2,182	12,540	1,852	10,650	2,053	11,800
7	2,090	12,000	1,975	11,350	2,370	13,620	2,105	12,100
8	1,782	10,250	2,828	16,240	1,762	10,130	2,652	15,250
9	1,762	10,130	2,219	12,750	1,854	10,650	1,205	6,930
10	2,320	13,320	1,938	11,130	1,873	10,780	1,963	11,290
11	1,473	8,470	2,226	12,800	2,118	12,180	1,900	10,920
12	2,948	16,940	2,463	14,180	2,840	16,320	2,270	13,050
13	2,360	13,580	2,638	15,150	2,270	13,070	1,810	10,400
14	1,768	10,170	1,928	11,080	2,526	14,520	1,515	8,710
15	2,175	12,500	2,116	12,170	1,267	7,280	2,640	15,190
16	1,854	10,650	3,050	17,520	2,220	12,780	1,449	8,330
17	2,244	12,900	1,854	10,650	1,377	7,910	1,726	9,920
18	2,005	11,530	2,635	15,130	1,412	8,120	731	4,210
19	1,935	11,120	2,395	13,770	1,369	7,870	2,058	11,820
20	2,440	14,030	2,445	14,050	1,822	10,480	1,850	10,620
21			2,148	12,340				
22			1,991	11,450				
Average	2,050	11,785	2,250	12,930	1,830	10,510	1,775	10,210
Maximum	2,948	16,940	3,050	17,520	2,840	16,320	2,652	15,250
Minimum	1,473	8,470	1,770	10,190	714	4,110	731	4,210

TABLE 3.—*Results of tests on poles, summarized by species and condition of seasoning.*

Species.	Number of tests.	Top diameter.	Volume.	Weight per cubic foot (oven dry).	Approximate age.	Rings per inch.	Per cent sap.	Per cent moisture.	Fiber stress at elastic limit.	Ratio to cedar.	Modulus of rupture.	Ratio to cedar.	Stiffness factor.	Ratio to cedar.	Modulus of elastic resilience.	Ratio to cedar.
Western red cedar:																
Cut green and air seasoned—		*Inches.*	*Cubic feet.*	*Pounds.*	*Years.*				*Pounds per sq. in.*	*Per cent.*	*Pounds per sq. in.*	*Per cent.*		*Per cent.*	*In. lbs. per cu. in.*	*Per cent.*
Average	20	6.98	9.5	21.4	84	18.4	32	15.1	4,430	100	6,885	100	6.75	100	0.94	100
Maximum	....	7.46	11.3	23.1	104	22.0	43	30.8	5,980	....	9,360	....	9.46	....	1.22	....
Minimum	....	6.15	7.5	19.3	55	13.0	21	12.0	2,900	....	5,090	....	4.43	....	.62	....
Lodgepole pine:																
Cut green and air seasoned—																
Average	22	7.36	9.9	27.6	162	34.0	48	21.9	5,280	119	7,680	112	8.62	127	1.00	106
Maximum	....	8.30	12.7	29.6	170	39.0	75	34.8	6,270	....	9,500	....	10.80	....	1.43	....
Minimum	....	6.70	8.1	25.5	144	29.0	34	18.5	3,830	....	5,190	....	6.35	....	.69	....
Fire killed 10 years—																
Average	19	7.50	10.7	25.4	155	31.8	32	16.9	4,327	98	5,481	80	6.25	93	.97	103
Maximum	....	9.25	14.5	29.3	189	42.0	60	36.2	6,130	....	7,480	....	8.72	....	1.62	....
Minimum	....	6.75	8.9	21.6	97	17.0	19	11.2	2,230	....	2,230	....	4.42	....	.34	....
Engelmann spruce:																
Fire killed 10 years—																
Average	20	7.23	11.2	22.3	164	34.3	....	16.3	3,489	79	4,378	64	4.97	74	.83	88
Maximum	....	8.00	13.7	26.3	210	46.0	....	32.8	5,210	....	6,070	....	6.97	....	1.25	....
Minimum	....	6.00	8.2	19.0	112	23.0	....	11.9	2,180	....	2,180	....	3.30	....	.44	....

A comparison based on the fiber stress developed is equivalent to one based on uniform ground-line diameter. In practice, however, it is customary to specify top diameters. On a basis of measured tapers and the fiber stresses found by test, the loads may be calculated for all shipments, using a uniform top diameter of 7 inches. Table 4 gives the calculated loads for such a comparison. The tapers used in the calculations were, for western red cedar, 0.098 inch per foot length; for the air-seasoned lodgepole pine, 0.077; for fire-killed lodgepole pine, 0.096; and for fire-killed Engelmann spruce, 0.130. These tapers do not include the flare of the butt. The length from top to the load point was taken as 19.5 in all cases. Since the strength of a pole varies as the cube of its diameter, it is evident that differences in taper will materially affect the strength. On a basis of equal top diameters it will be seen from Table 4 that—

1. There is practically no difference in strength between air-seasoned lodgepole pine and western red cedar. In stiffness the lodgepole pine poles exceeded the cedar by about 25 per cent.

2. The fire-killed poles, both lodgepole pine and Engelmann spruce, were practically equal to the cedar in strength at elastic limit and about 20 per cent below it at the maximum load.

TABLE 4.—*Strength of poles compared on a basis of 7-inch tops.*

Species.	Seasoning condition.	Load at elastic limit.		Maximum load.	
		Average.	Ratio to red cedar.	Average.	Ratio to red cedar.
		Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
Western red cedar	Cut green and air seasoned	7,800	100	12,000	100
Lodgepole pine	do	8,000	103	11,620	97
Do	Fire killed 10 years	7,470	96	9,500	79
Engelmann spruce	do	7,500	96	9,400	78

SMALL, CLEAR PIECES CUT FROM POLES.

Table 5 gives the results of tests on small, clear pieces in bending, compression parallel to grain, compression perpendicular to grain, and shearing. For each pole the average strength values for all pieces taken from it are given, and at the bottom of the tables are the averages of all minor tests for the species.

Table 6 gives the average strength values of minor tests summarized by species and condition of seasoning. An examination of the average results shows in general very comparable values for the fire-killed pine and spruce and for the cedar. The cedar, however, falls about 16 per cent below the pine in shearing strength and the spruce about 12 per cent below it in crushing strength. The lodgepole pine from Montana showed a bending strength nearly 40 per cent greater and a crushing strength 18 per cent greater than the fire-killed lodgepole pine. It might seem at first sight that these differences were due to deterioration on the part of the fire-killed material, but an analysis of the values in regard to weight and a comparison with values obtained from other tests on lodgepole pine indicate that deterioration is not the probable cause of the difference. It has been proved conclusively that in any species the strength of the clear wood varies directly with its dry weight.

TABLE 5.—*Summary of tests on small, clear pieces cut from poles.*

WESTERN RED CEDAR CUT GREEN AND AIR SEASONED.

Number of pole from which taken.	Bending.									Compression parallel to grain.					Compression perpendicular to grain.			Shearing.		
	Number of tests.	Per cent moisture.	Weight per cubic foot (oven dry).	Per cent summerwood.	Per cent sap.	Modulus of rupture (pounds per square inch).	Fiber stress at elastic limit (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Modulus of elastic resilience (inch pounds per cubic inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Number of tests.	Per cent moisture.	Shear strength (pounds per square inch).
			Lbs.																	
1	4	8.6	22.8	22	12	8,045	5,962	1,418	1.44	3	6.5	4,050	6,803	1,778	3	7.5	520	2	6.4	1,020
2	6	8.5	23.0	22	4	9,357	5,955	1,089	1.85	2	6.4	4,290	6,845	1,642	7	7.2	573	5	6.2	1,139
3	5	8.0	21.1	23	2	8,706	5,930	1,039	1.90	1	6.7	4,500	5,190	1,190	3	6.9	565	3	6.4	857
4	11	8.4	22.1	21	10	8,574	5,295	1,040	1.57	6	6.6	4,044	6,236	1,152	5	7.1	521	7	6.4	820
5	4	8.1	22.7	20	25	9,282	6,270	1,122	1.95	2	6.7	4,810	6,705	1,295	1	6.9	605	4	6.2	791
6	7	8.0	23.6	24	2	10,361	6,181	1,214	1.78	2	6.4	6,050	7,285	1,540	2	6.7	722	7	6.0	1,064
7	6	7.7	19.6	18	9	7,048	4,737	868	1.46	4	6.6	3,405	5,135	1,125	3	7.6	532	3	6.1	805
8	9	7.9	21.7	22	6	9,563	5,857	1,198	1.64	5	6.4	5,152	6,666	1,342	4	7.0	528	5	6.2	935
9	5	7.8	22.4	20	5	10,190	6,294	1,322	1.71	3	6.4	4,887	6,360	1,258	4	6.6	514	4	6.2	769
10	3	7.6	23.4	24	10	10,717	6,390	1,292	1.78	3	6.4	4,707	6,666	3,593	2	6.4	800	3	6.1	1,065
11	5	7.7	22.4	27	4	9,516	6,004	1,296	1.55	3	6.6	5,230	6,413	1,458	2	6.6	500	4	6.1	950
12	8	7.7	23.9	26	3	9,036	5,200	1,040	1.50	2	6.6	4,320	6,910	1,215	3	6.5	535	2	6.2	1,048
13	1	7.5	23.3	17	0	9,850	5,780	1,301	1.42	1	6.7	4,500	6,390	1,225	3	6.4	635	2	5.9	1,078
14	4	7.4	22.2	24	0	9,672	6,742	1,233	2.05	1	6.3	5,030	6,810	1,390	1	6.3	500	6	5.9	1,097
15	4	7.7	22.4	21	1	9,225	6,325	1,179	1.90	1	6.1	5,000	6,330	1,410	2	6.6	450	4	5.9	1,088
16	8	8.0	22.0	24	1	10,006	6,928	1,376	1.94	4	6.3	5,402	6,930	1,646	4	6.6	504	7	5.8	965
17	3	7.6	23.3	24	0	9,790	6,733	1,420	1.78	1	6.2	6,040	7,330	1,620	3	6.2	533	3	6.1	902
18	4	7.5	21.6	23	12	9,018	6,338	1,108	2.02	4	6.3	4,550	6,275	1,280	3	6.2	402	3	6.1	978
19	4	7.5	20.8	16	7	8,855	6,308	1,245	1.78	4	6.1	5,085	6,310	1,376	3	6.4	405	2	6.2	680
20	4	7.4	23.9	22	1	10,890	6,555	1,410	1.71	4	6.1	6,058	7,585	1,581	3	6.3	633	2	6.2	1,020
Average	[1] 105	7.9	22.3	22	2	9,305	5,997	1,185	1.73	[1] 56	6.4	4,825	6,540	1,373	[1] 61	6.8	538	[1] 78	6.1	959
Maximum	......	9.2	25.0	30	30	12,090	7,910	1,666	2.52	......	6.9	7,580	7,880	1,880	......	8.8	1,000	......	6.7	1,505
Minimum	......	7.0	18.2	12	0	5,280	3,120	615	0.53	......	5.9	1,990	4,350	640	......	6.1	300	......	5.4	525

[1] Total.

TABLE 5.—*Summary of tests on small, clear pieces cut from poles*—Continued.

LODGEPOLE PINE CUT GREEN AND AIR SEASONED.

Number of pole from which taken.	Bending.									Compression parallel to grain.					Compression perpendicular to grain.			Shearing.		
	Number of tests.	Per cent moisture.	Weight per cubic foot (oven dry).	Per cent summerwood.	Per cent sap.	Modulus of rupture (pounds per square inch).	Fiber stress at elastic limit (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Modulus of elastic resilience (inch pounds per cubic inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Number of tests.	Per cent moisture.	Shear strength (pounds per square inch).
			Lbs.																	
1	2	7.7	28.2	......	0	11,770	8,520	1,348	3.00	2	8.0	......	6,960	......	......	......	......	1	7.8	1,135
2	2	8.2	28.1	......	0	12,680	9,112	1,520	3.04	3	8.4	......	7,190	......	......	......	......	2	8.1	992
3	2	8.2	31.3	......	0	12,125	8,520	1,232	3.31	3	8.7	......	7,023	......	......	......	......	3	7.7	1,082
4	2	8.2	31.0	......	0	14,525	11,345	1,640	4.41	3	8.3	......	8,713	......	......	......	......	3	7.8	1,093
5	2	8.0	30.3	......	0	13,995	8,705	1,728	2.44	3	9.2	......	8,527	......	......	......	......	2	7.6	1,165
6	1	8.9	31.6	......	0	12,700	8,400	1,410	2.78	2	8.2	......	7,730	......	......	......	......	1	8.6	1,005
7	1	10.1	34.1	......	0	11,850	8,620	1,370	3.01	3	8.8	......	6,810	......	......	......	......	1	7.9	879
8	2	7.8	31.3	......	0	15,010	10,035	1,810	3.10	2	7.8	......	7,710	......	......	......	......	0	......	......
9	1	7.4	28.8	......	0	11,580	5,460	1,067	2.18	3	7.9	......	5,480	......	......	......	......	2	7.5	1,002
10	0	......	......	......	......	......	......	......	......	2	8.2	......	8,518	......	......	......	......	2	7.6	1,248
11	2	7.6	30.9	......	0	13,785	9,500	1,811	2.78	3	8.0	......	8,317	......	......	......	......	1	7.6	1,116
12	4	8.4	29.9	......	0	11,825	7,954	1,413	2.52	3	8.1	......	7,745	......	......	......	......	0	......	......
13	2	8.0	29.8	......	0	12,755	8,645	1,562	2.67	2	8.1	......	8,295	......	......	......	......	4	7.8	1,185
14	2	7.5	29.5	......	0	11,885	7,795	1,428	2.37	3	8.2	......	7,165	......	......	......	......	2	8.3	1,276
15	2	8.6	33.0	......	0	14,775	10,665	1,778	3.56	2	7.9	......	8,880	......	......	......	......	1	8.2	1,275
16	1	8.0	30.3	......	0	14,480	6,500	1,985	1.18	2	8.0	......	7,955	......	......	......	......	1	8.3	1,002
17	2	8.0	30.2	......	0	11,865	7,425	1,402	2.19	2	7.8	......	7,228	......	......	......	......	2	8.3	1,402
18	3	8.1	30.6	......	0	13,717	9,293	1,709	2.82	3	7.9	......	8,275	......	......	......	......	1	8.2	1,103
19	2	8.4	27.3	......	0	9,205	7,040	1,312	2.10	2	8.0	......	6,895	......	......	......	......	3	8.4	995
20	2	8.2	30.6	......	25	12,265	7,580	1,412	2.26	3	8.3	......	8,122	......	......	......	......	1	8.2	1,335
21	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	0	......	......
22	3	8.3	29.6	......	0	12,890	8,520	1,408	2.97	2	8.2	......	8,085	......	......	......	......	2	8.6	1,127
Average	[1] 40	8.1	30.2	......	0.6	12,775	8,600	1,520	2.78	[1] 53	8.2	......	7,672	......	......	......	......	[1] 35	8.0	1,129
Maximum	......	10.1	34.5	......	25	16,080	10,660	1,985	5.14	......	12.2	......	9,780	......	......	......	......	......	8.8	1,735
Minimum	......	7.3	26.4	......	0	7,580	5,460	1,056	1.18	......	7.5	......	4,595	......	......	......	......	......	6.6	800
LODGEPOLE PINE FIRE KILLED 10 YEARS.																				
1	2	7.7	21.6	12	6	7,402	4,820	984	1.31	2	8.2	3,395	5,050	990	4	7.4	602	2	7.3	918
2	2	7.6	25.0	12	6	6,525	4,350	917	1.16	1	7.9	3,810	5,940	1,090	2	7.7	799	3	7.4	1,145

3	3	8.2	24.8	19	7	7,400	5,097	1,224	1.18	3	8.1	4,965	5,743	1,283	3	8.4	640	0	......	......
4	3	7.5	26.3	13	0	7,817	5,267	1,032	1.49	1	8.4	5,320	6,920	1,310	0	......	......	2	7.6	1,242
5	2	7.6	25.0	12	5	9,655	5,955	1,344	1.50	1	8.3	4,250	5,710	1,270	2	8.1	645	1	7.7	995
6	4	7.9	28.9	22	0	9,740	6,014	1,174	1.72	2	8.2	4,970	7,365	......	2	8.5	1,092	2	7.6	1,100
7	3	8.1	28.1	24	6	10,720	7,777	1,429	2.37	2	8.1	7,200	8,635	2,010	2	8.8	956	1	7.0	1,220
8	4	7.5	24.4	20	25	9,175	6,748	1,339	1.89	1	8.1	4,875	5,800	1,500	3	8.3	603	2	8.0	795
9	2	7.3	24.4	16	0	7,360	5,925	1,052	1.88	3	7.9	5,220	6,147	1,237	3	8.3	678	0	......	......
10	1	7.6	24.2	17	0	10,340	6,530	1,365	1.73	0	......	......	......	......	1	8.6	525	2	7.5	1,115
11	2	7.7	26.4	13	10	11,785	7,300	1,542	1.92	3	8.0	6,738	7,360	1,690	2	8.6	682	2	7.5	1,208
12	2	8.1	25.8	17	15	9,290	4,890	1,052	1.26	2	7.8	4,138	5,555	960	3	8.3	681	4	8.1	1,236
13	0	......	......	......	......	......	......	......	......	0	......	......	......	......	1	7.5	766	0	......	......
14	3	7.0	28.5	17	0	8,872	6,070	1,174	1.80	2	7.8	6,002	7,365	1,695	0	......	......	1	7.9	1,500
15	2	8.0	24.4	14	25	9,690	6,580	1,145	2.10	3	8.1	4,667	5,700	1,280	2	8.2	616	0	......	......
16	2	8.0	26.2	18	0	10,455	6,778	1,364	1.88	2	8.8	5,645	6,670	1,430	3	8.8	781	2	7.6	1,282
17	1	8.3	27.7	18	4	10,340	7,050	1,460	1.89	3	8.4	5,970	6,663	1,380	4	8.9	910	0	......	......
18	1	8.6	25.6	15	0	7,660	6,770	1,015	2.50	2	8.6	4,170	5,095	1,230	2	8.4	571	1	7.6	1,150
19	1	8.4	25.6	18	0	8,830	7,110	1,266	2.22	2	8.3	6,160	7,105	1,480	2	8.2	948	2	8.0	1,200
20	1	8.3	27.0	18	0	9,460	7,610	1,365	2.36	2	8.8	6,295	7,565	1,465	1	8.0	975	1	8.2	1,185
Average	[1] 41	7 8	25.9	17	3	9,049	6,145	1,217	1.75	[1] 37	8.2	5,278	6,486	1,361	[1] 42	8.3	740	[1] 28	7.7	1,148
Maximum	......	8.6	30.3	25	25	12,350	8,310	1,622	2.68	......	9.3	7,200	8,770	2,010	......	10.0	1,210	......	10.2	1,500
Minimum	......	6.6	21.5	10	0	5,190	3,280	822	0.73	......	7.4	3,000	4,560	890	......	6.8	402	......	6.3	660

ENGELMANN SPRUCE FIRE KILLED 10 YEARS.

1	2	8.0	22.4	24	0	7,192	5,580	1,154	1.50	4	8.2	4,878	5,690	1,290	4	8.0	632	1	8.5	905
2	1	8.1	21.8	15	0	7,860	4,260	1,071	.94	2	7.8	......	5,360	......	3	8.5	580	1	8.0	835
3	3	8.0	20.6	21	0	7,170	5,630	923	1.92	3	7.8	3,370	4,740	1,018	3	8.2	501	1	8.4	840
4	4	7.7	27.9	18	0	10,860	7,048	1,560	1.85	0	......	......	......	......	1	8.2	765	1	8.7	1,390
5	2	8.0	22.6	18	0	7,308	5,655	1,149	1.54	1	......	4,050	4,800	1,140	1	8.2	600	1	8.4	1,050
6	4	7.5	23.4	14	0	10,282	7,149	1,376	2.08	3	7.6	5,025	5,953	1,255	2	8.2	604	0	......	......
7	4	8.0	22.9	12	0	10,342	6,839	1,297	2.01	1	8.0	2,560	5,780	1,535	3	8.3	681	3	8.1	1,132
8	2	8.7	25.8	18	0	10,940	8,038	1,528	2.34	2	8.2	5,600	6,395	1,250	3	8.4	834	1	7.7	1,325
9	3	8.1	21.4	15	0	7,925	5,295	1,041	1.51	0	......	......	......	......	3	8.5	526	1	7.3	1,100
10	5	7.8	23.1	17	0	8,970	5,926	1,138	1.78	1	7.9	4,680	6,120	1,080	3	8.2	718	2	8.0	972
11	0	......	......	......	......	......	......	......	......	1	7.5	4,560	5,230	1,180	1	8.1	900	4	7.0	1,036
12	0	......	......	......	......	......	......	......	......	0	......	......	......	......	2	7.4	839	2	8.2	1,210
13	3	7.8	25.0	16	0	9,857	6,337	1,417	1.58	2	7.6	6,750	6,825	1,610	4	7.6	596	3	7.8	1,323
14	3	7.8	21 5	14	0	8,460	5,910	1,111	1.77	3	7.9	4,783	5,567	1,147	2	6.9	638	3	7.9	1,178
15	4	7.8	23.0	17	0	8,128	5,538	1,078	1.62	2	7.8	4,605	5,405	1,210	5	7.7	629	5	7.8	1,102
16	3	8.2	22.0	20	0	8,687	5,197	1,002	1.55	2	7.7	4,870	5,660	1,040	2	7.8	532	2	8.2	1,208
17	2	8.4	25.7	24	0	8,658	5,625	1,098	1.60	4	7.7	4,412	6,205	1,461	3	8.1	503	2	8.5	1,370
18	0	......	......	......	......	......	......	......	......	0	......	......	......	......	2	8.0	418	2	7.8	945
19	3	8.0	25.1	21	0	11,277	7,192	1,383	2.08	0	......	......	......	......	2	7.8	726	3	8.1	1,292
20	6	8.1	21.7	13	0	8,162	6,027	1,002	2.03	4	8.2	4,430	5,445	907	5	8.0	532	2	7.5	1,208
Average	[1] 54	8.0	23.3	17	0	9,045	6,163	1,194	1.80	[1] 35	7.9	4,585	5,696	1,208	[1] 54	8.0	621	[1] 40	7.9	1,142
Maximum	......	8.8	28.3	25	0	12,360	9,100	1,620	3.00	......	9.0	6,750	7,000	1,700	......	8.9	995	......	8.9	1,595
Minimum	......	7.1	19.8	10	0	6,050	4,260	850	.87	......	7.3	2,030	4,650	840	......	6.2	377	......	6.1	555

[1] Total.

TABLE 6.—*Results of tests on small, clear specimens cut from poles, summarized by species and condition of seasoning.*

Species and condition of pole from which cut.	Bending.								Compression parallel to grain.				Compression perpendicular to grain.		Shearing.	
	Number of tests.	Per cent moisture.	Rings per inch.	Weight per cubic foot (oven dry).	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Modulus of elastic resilience.	Number of tests.	Crushing strength at elastic limit.	Modulus of elasticity.	Maximum crushing strength.	Number of tests.	Crushing strength at elastic limit.	Number of tests.	Shearing strength.
				Pounds.	*Pounds per square inch.*	*Pounds per square inch.*	*1,000 pounds per square inch.*	*Inch pounds per cubic inch.*		*Pounds per square inch.*	*1,000 pounds per square inch.*	*Pounds per square inch.*		*Pounds per square inch.*		*Pounds per square inch.*
Western red cedar:																
Cut green and air seasoned—																
Average	105	7.9	16.9	22.3	5,997	9,305	1,185	1.73	56	4,825	1,373	6,540	61	538	78	959
Maximum	....	9.2	29.0	25.0	7,910	12,090	1,666	2.52	....	7,580	1,880	7,880	....	1,000	....	1,505
Minimum	....	7.0	6.0	18.2	3,120	5,280	615	0.53	....	1,990	640	4,350	....	300	....	525
Lodgepole pine:																
Cut green and air seasoned																
Average	40	8.1	31.9	30.2	8,600	12,775	1,520	2.78	53	....	....	7,672	....	....	35	1,129
Maximum	....	10.1	49.0	34.5	10,660	16,080	1,985	5.14	....	....	....	9,780	....	....	....	1,735
Minimum	....	7.3	12.0	26.4	5,460	7,580	1,056	1.18	....	....	....	4,595	....	....	....	800
Fire killed 10 years—																
Average	41	7.8	26.1	25.9	6,145	9,049	1,217	1.75	37	5,278	1,361	6,486	42	740	28	1,148
Maximum	....	8.6	56.0	30.3	8,310	12,350	1,622	2.68	....	7,200	2,010	8,770	....	1,210	....	1,500
Minimum	....	6.6	13.0	21.5	3,280	5,190	822	0.73	....	3,000	890	4,560	....	402	....	660
Engelmann spruce:																
Fire killed 10 years																
Average	54	8.0	35.1	23.3	6,163	9,045	1,194	1.80	35	4,585	1,208	5,696	54	621	40	1,142
Maximum	....	8.8	66.0	28.3	9,100	12,360	1,620	3.00	....	6,750	1,700	7,000	....	995	....	1,595
Minimum	....	7.1	19.0	19.8	4,260	6,050	850	0.87	....	2,030	840	4,650	....	377	....	555

In figure 7 the weight-strength relations are plotted for bending tests on small specimens cut from the tested lodgepole pine poles and for similar specimens taken from other material grown in Colorado and Wyoming, cut green and air seasoned. It will be seen that fire-killed lodgepole pine is equal in strength to the Colorado and Wyoming material cut green and air seasoned, and that the Montana material gave higher strength values because it was exceptionally heavy and much above the normal for Colorado-grown timber of which the fire-killed poles were representative. The soundness of

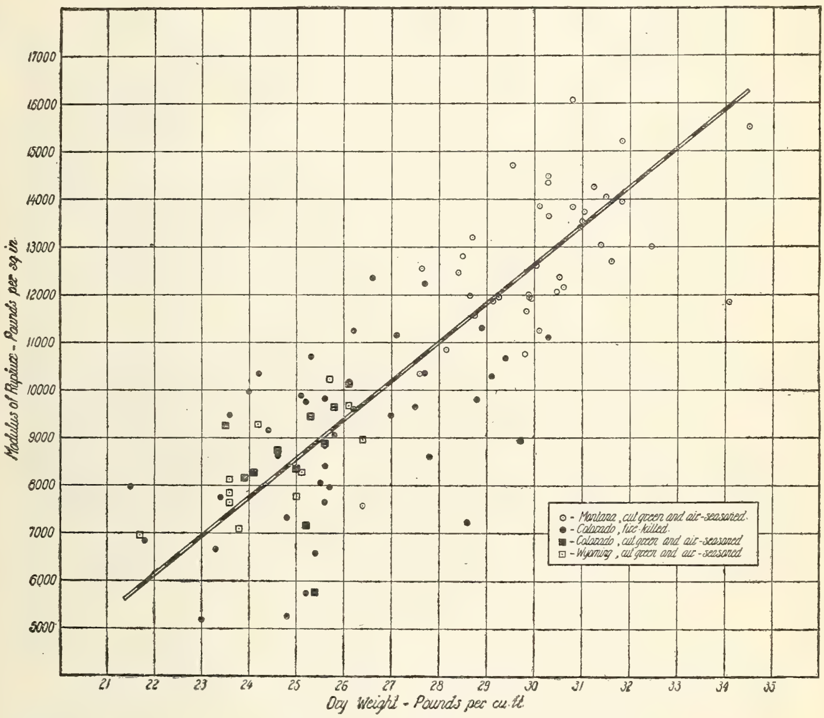

FIG. 7.—Weight-strength relations for clear, dry lodgepole pine.

the sticks cut from the fire-killed material also indicates that such timber has no inherent defect due to having been killed by fire. It seems more reasonable to regard it simply as seasoned wood, and to assume that deterioration due to age or exposure, if present, would be indicated by the same signs of decay that are apparent in any unsound material.

The relation between the stresses shown by the individual poles and those shown by the minor tests on the material cut from them is presented in figure 8. It should be remembered that the moisture content of the small specimens was only 8 per cent, as compared with an average of about 16 per cent for the poles. The green-cut

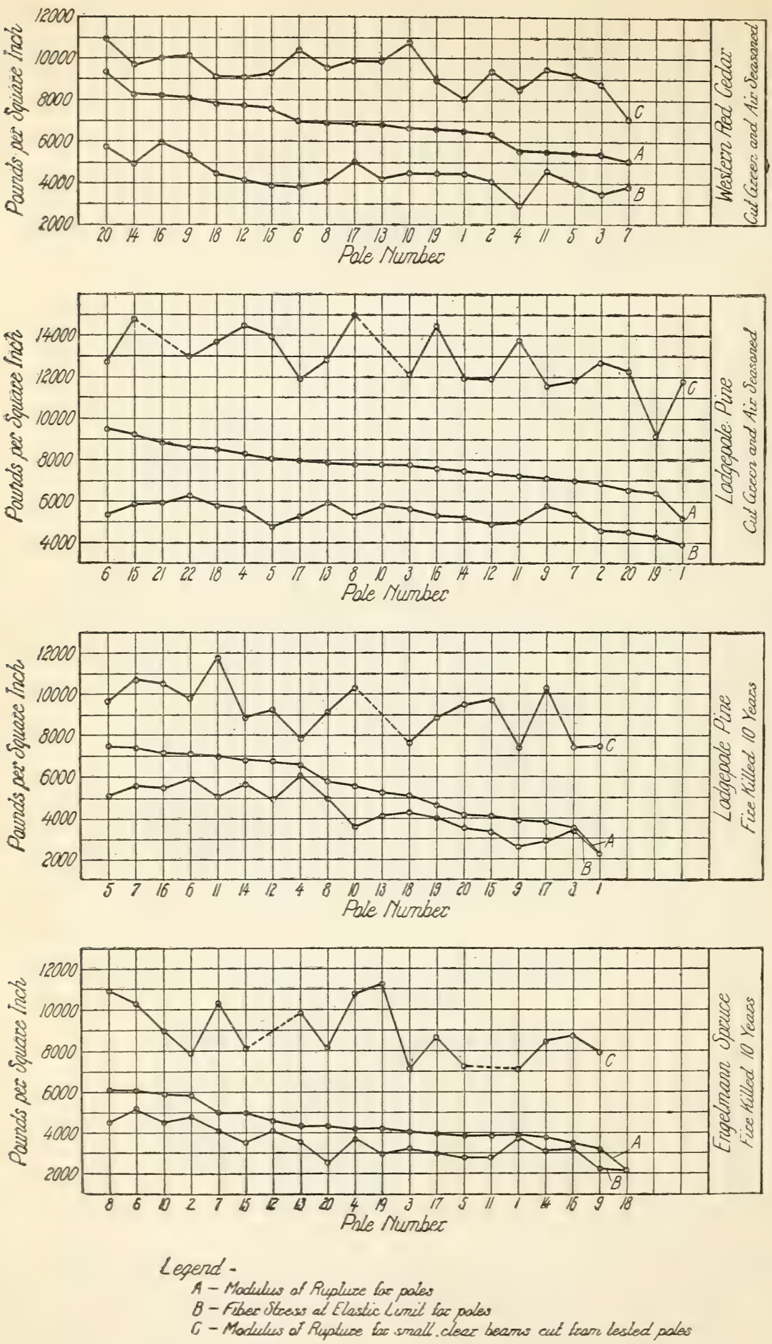

FIG. 8.—Relation of fiber stress of poles and modulus of rupture of small, clear beams cut from them to the modulus of rupture of poles.

lodgepole pine shipment averaged about 22 per cent moisture, though the outer shell of the poles was somewhat drier (see fig. 3). This would tend to make the difference between the strength of the poles and the actual strength of the material in it much greater than was the case. The curve given on page 10 of Forest Service Circular 108, The Strength of Wood as Influenced by Moisture, shows that, for eastern spruce, strength in bending will be reduced by about 30 per cent when the moisture content is increased from 8 per cent to 16 per cent. Tests on lodgepole pine from Wyoming indicate a reduction, under similar circumstances, of about 25 per cent. The curves shown in figure 8 have, however, been plotted with the values as obtained from the tests.

The curves, arranged in order of the modulus of rupture of the poles from highest to lowest, show the relation between the modulus of rupture of the small, clear sticks and the fiber stress of the poles at the elastic limit and maximum load. The position and number of checks, knots, and other defects, rather than the quality of the clear wood, determines the grade of a pole. While the curve for the modulus of rupture of the small pieces is erratic, as would be expected from the rather small number of tests averaged for each pole, it shows a tendency to fall with a fall in strength of the poles, indicating the influence of the quality of the clear wood on the strength of the poles. The most important relation shown by the curves is that the ratios between pole and minor strengths are not the same for the different species, indicating that it is not safe to compare species for use as poles on the basis of the strength of their clear material. For example, western red cedar gave an average modulus of rupture for the small, clear beams of 9,305 pounds per square inch, and the lodgepole pine from Montana averaged 12,775. While the strength of the clear material of the pine is thus 37 per cent higher than that of the cedar, the average strength of the poles was a little less than 12 per cent higher. The ratios of the average modulus of rupture of the poles to that of the clear material for two conditions of moisture is as follows:

Kind of poles.	As tested at 8 per cent.	As estimated [1] at 16 per cent.
Western red cedar	0.74	0.98
Lodgepole pine:		
Green cut	.60	.80
Fire killed	.60	.80
Engelmann spruce, fire killed	.48	.65

[1] On the basis that an increase in moisture from 8 to 16 per cent causes a 25 per cent reduction in strength.

CONCLUSIONS.

The tests on poles and specimens cut from them show that—

1. Air-seasoned lodgepole pine poles cut from live timber in Montana were fully equal in strength to the cedar poles tested. In actual stress developed they were superior, but on account of the greater taper of the cedar poles this advantage was lost in a comparison based on equal top diameters, the dimension usually specified.

2. Cedar poles were superior to the pine and spruce poles cut from a fire-killed area in Colorado in maximum load developed. The three shipments were, however, practically equal at the elastic limit. Were the native poles to be used in place of cedar without change of specifications, it would follow that the factor of safety would be reduced one-fifth for conditions at failure, but would remain the same for stresses at the elastic limit.

3. The fire-killed pine, after standing 10 years, did not show deterioration to any appreciable extent when compared to seasoned lodgepole pine cut from representative live trees in Wyoming and Colorado. The advantage in strength of the material from the lodgepole pine poles from Montana can be accounted for by the fact that it was above normal in weight—at least for lodgepole pine from the southern part of its range.

4. The ratio between the strength of the poles and the strength of the clear material cut from them is not constant for the different kinds of wood. This "efficiency" factor varied from 0.74 to 0.48 of the strength of the clear wood when the comparison is made as tested, and from 0.98 to 0.65 when compared on the basis of values estimated to represent the same moisture condition in the small pieces as existed in the poles when tested. The values were highest for the cedar and lowest for the spruce, the pine representing an average for the three species.

POLE TESTS BY THE PACIFIC TELEPHONE & TELEGRAPH CO.

The Pacific Telephone & Telegraph Co. made tests on 81 poles of western red cedar and Port Orford cedar at the pole yards of the Western Electric Co. near Richmond, Cal. These poles were 25 and 30 feet in length, with 6, 7, and 8 inch top diameters, and 35 feet in length, with 7, 8, and 9 inch tops.

The method employed in these tests makes it impossible to make any accurate comparisons of stress values with those obtained in the Forest Service tests. In the telephone company's tests stresses are figured for the point of failure, while the Forest Service tests are figured for the load point or ground line, theoretically the point of greatest stress.

In the telephone company's tests the poles were tested horizontally, with 6 feet of the butt end of the pole held firmly between four 12 by 12 inch posts set in the ground. The load was applied to the top of the pole, by means of a winch, at a rate of 1 foot per minute. A direct-reading dynamometer was placed in the line connecting the winch with the top of the pole. The top end of the pole was supported on a dolly with truck casters which traveled on a piece of sheet iron, thus eliminating friction. Readings of the movement of a nail driven into the top of the pole were taken for each 100 pounds increment of load.

The Pacific Telephone & Telegraph Co. has kindly permitted the use of their test data, and Table 7 is compiled from their report. Comparison of the equivalent top load in Table 2 with the top load for 7-inch by 25-foot poles in Table 7 shows a difference of only 5 per cent, while the calculated stresses are about 20 per cent greater for the Forest Service results. This difference, as already stated, is probably due to the different methods used, both for calculating the stress and for supporting the butt of the pole.

Reference to Table 7 shows that there is no consistent variation when poles of the same top diameter but of different lengths are compared. However, Table 8, compiled from Table 7, shows a very marked relation between top diameter and top breaking load in the three classes of poles tested by the Pacific Telephone & Telegraph Co.

TABLE 7.—*Results of pole tests made by the Pacific Telephone & Telegraph Co.*

WESTERN RED CEDAR FROM IDAHO.

Top diameter.	Length.	Number of poles tested.	Average values of—						
			Weight of poles.	Weight per cubic foot.	Moisture.	Rings per inch.	Sap.	Top load at failure.	Modulus of rupture.
Inches.	*Feet.*		*Pounds.*	*Pounds.*	*Per cent.*		*Per cent.*	*Pounds.*	*Lbs. per sq. in.*
6	25	3	205	22.0	9.4	13.7	38.0	1,853	6,221
7	25	4	244	23.0	9.2	23.0	27.6	1,948	5,712
8	25	3	282	22.9	10.2	18.3	26.3	2,667	5,290
6	30	4	283	22.4	13.6	20.1	28.1	1,590	5,126
7	30	4	344	26.1	10.0	23.3	24.5	2,434	5,549
8	30	3	382	23.4	9.1	23.4	21.4	2,740	5,308
7	35	3	477	22.1	8.1	19.3	40.8	2,000	5,080
8	35	3	471	19.4	10.4	18.5	25.7	2,125	4,391
9	35	3	522	21.5	10.2	22.6	24.9	2,992	4,755

WESTERN RED CEDAR FROM OREGON AND WASHINGTON.

6	25	3	204	24.1	8.7	24.4	41.6	1,470	5,525
7	25	3	213	19.8	15.1	6.6	41.2	1,625	4,481
8	25	3	238	19.8	18.0	9.5	30.1	2,072	4,816
6	30	3	255	21.7	17.0	7.2	36.8	1,352	5,784
7	30	3	240	18.8	7.4	9.3	33.3	1,597	7,006
8	30	3	395	22.8	15.4	11.3	29.2	2,385	3,146
7	35	3	331	21.1	9.2	8.0	32.7	1,712	6,408
8	35	3	546	24.6	34.0	6.8	38.2	1,888	4,349
9	35	3	597	24.8	11.6	24.3	17.4	3,257	5,665

TABLE 7.—*Results of pole tests made by the Pacific Telephone & Telegraph Co.*—Contd.

PORT ORFORD CEDAR.

Top diameter.	Length.	Number of poles tested.	Average values of— Weight of poles.	Weight per cubic foot.	Moisture.	Rings per inch.	Sap.	Top load at failure.	Modulus of rupture.
Inches.	*Feet.*		*Pounds.*	*Pounds.*	*Per cent.*		*Per cent.*	*Pounds.*	*Lbs. per sq. in.*
6	25	3	256	31.3	11.6	16.3	....	2,027	7,616
7	25	3	315	24.8	10.7	25.6	....	3,277	7,896
8	25	4	460	26.6	13.3	10.3	....	3,740	6,058
6	30	3	375	24.3	8.6	15.3	....	2,518	6,817
7	30	3	397	25.2	20.5	15.0	....	2,790	7,332
8	30	3	441	24.0	9.6	14.7	....	3,577	7,824
7	35	3	585	30.4	10.1	9.0	....	3,123	6,851
8	35	3	591	28.1	9.7	21.0	....	3,057	6,928

TABLE 8.—*Relation between top diameters and top breaking loads.*

[Pacific Telephone & Telegraph Co.'s tests.]

Length of poles.	Top diameter.	Western red cedar from Idaho.		Western red cedar from Oregon and Washington.		Port Orford cedar.	
		Number of poles.	Average top breaking load.	Number of poles.	Average top breaking load.	Number of poles.	Average top breaking load.
	Inches.		*Pounds.*		*Pounds.*		*Pounds.*
25 and 30 feet	6	7	1,703	6	1,411	6	2,272
25, 30, and 35 feet	7	11	2,139	9	1,645	9	3,063
25, 30, and 35 feet	8	9	2,511	9	2,115	11	3,169
35 feet	9	3	2,992	3	3,257	....	....

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TABLE 7.—*Results of pole tests made by the Pacific Telephone & Telegraph Co.*—Contd.

PORT ORFORD CEDAR.

Top diameter.	Length.	Number of poles tested.	Average values of— Weight of poles.	Weight per cubic foot.	Moisture.	Rings per inch.	Sap.	Top load at failure.	Modulus of rupture.
Inches.	*Feet.*		*Pounds.*	*Pounds.*	*Per cent.*		*Per cent.*	*Pounds.*	*Lbs. per sq. in.*
6	25	3	256	31.3	11.5	16.5	....	2,027	7,616
7	25	3	315	24.8	10.7	25.6	....	3,277	7,806
8	25	4	400	26.6	13.3	18.3	....	3,740	6,058
6	30	3	375	24.3	8.6	15.3	....	2,518	6,317
7	30	2	397	25.2	20.5	15.0	....	2,380	7,582
8	30	2	441	24.0	9.6	14.7	....	2,377	7,824
7	35	[illegible]	585	30.4	10.1	9.0	....	3,123	6,857
8	35	[illegible]	590	28.4	9.7	21.0	....	3,057	6,928

TABLE 8.—*Relation between top diameters and top breaking loads.*

[Pacific Telephone & Telegraph Co.'s tests.]

Length of poles.	Top diameter.	Western red cedar from Idaho. Number of poles.	Western red cedar from Idaho. Average top breaking load.	Western red cedar from Oregon and Washington. Number of poles.	Western red cedar from Oregon and Washington. Average top breaking load.	Port Orford cedar. Number of poles.	Port Orford cedar. Average top breaking load.
	Inches.		*Pounds.*		*Pounds.*		*Pounds.*
25 and 30 feet	6	7	1,702	8	1,517	6	2,272
25, 30, and 35 feet	7	11	2,139	9	1,846	9	3,063
30, 35, and 40 feet	8	9	2,511	9	2,115	11	3,169
40 feet	9	5	2,992	3	3,257	....	....

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